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Manure Treatment Technologies

Recommendations from the Manure Treatment Technologies Expert Panel to the Chesapeake Bay Program's Water Quality Goal Implementation Team to define Manure Treatment Technologies as a Best Management Practice

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Table TCC.1. Default Transfer Efficiencies for Thermochemical Conversion Processes.

Thermochemical Conversion Process	Transfer Efficiency (%)		
	NVE	NSE	PSE
Combustion	85	15	100
Gasification	85	15	100
Pyrolysis	25	75	100

Review of Available Science on Thermochemical Conversion Processes

The primary thermochemical conversion processes currently evaluated and utilized within the Chesapeake Bay Watershed are combustion, gasification and pyrolysis. Combustion of manure yields heat that must be used immediately; thus, this method does not provide a storable energy product. As such, pyrolysis and gasification have been the focus of most research, largely due to their product versatility. Table TCC.2 shows the defining control parameters of each thermochemical conversion process. Major end products of each process and their relative distribution range are given in Table TCC.3. The values shown in Table TCC3 are meant to be a qualitative comparison of the technologies rather than a quantitative reference on product distribution (Boateng et al, 2015). Quantity and quality of end product are dependent on operating temperature, reaction medium, heating rate, residence time, and ash content of feedstock. Feedstock particle size, mode of operation (batch or continuous), heating technique, and feedstock homogenization are secondary process factors affecting the efficiency of operation. Approximate percent of feedstock total solids, total nitrogen, and total phosphorus based on feedstock dry matter, ash content, and temperature range is given in Table TCC.4.

Process Factors

Operating Temperature plays a major large role in the volatilization of N from manure handling systems. Combustion systems typically operate at high temperatures (>1500˚F) and with excess oxygen associated with the process, much of the nitrogen is converted to various gaseous forms. Gasification processes cover a wide range of temperatures. Generally, as the operating temperature is reduced, the amount of nitrogen retained in the ash/char increases. Below 1,500° F, 75% of manure N is retained in char. Above 1,500° F, as much as 85% of manure N is lost in gaseous emissions. Even though nitrogen retention in ash/char does not have the drastic change at a given temperature, using 1500˚F provides a guide to use for systems without monitoring or testing data. This temperature could also vary depending on the system and operational performance.

Reaction Medium is an easy parameter with which to categorize heat treatment processes. In order to consume all the reactionary portion of the feedstock, combustion processes operate under an excess of oxygen. Gasification operates with a nominal amount, usually sub-stoichiometric, of O_2. Pyrolytic processes operate without O_2 present. As more oxygen is added to the system, more gases are released -- including the volatile gases Ammonia (NH_3) and light hydrocarbons.

Table TCC.2. Thermochemical Conversion Processes Conditions.

Thermochemical Conversion Process	Feedstock Consistency	Process Conditions			
		Temperature (°F)	Pressure (atm)	Aeration Level	Residence Time
Combustion	Solid	1,500 - 3,000	~1	Excess O_2	Minutes to Hours
Gasification	Solid	1,400 - 2,700	~1	Limited O_2	Minutes to Hours
Fast Pyrolysis	Solid	750 - 1,100	~1	No O_2	Seconds
Slow Pyrolysis	Solid	575 - 1,475	~1	No O_2	Hours to Days

Table TCC.3. Major End Product and End Product Distribution Ranges based on Ash-Free Feedstock Material for Thermochemical Conversion Processes.

Thermochemical Conversion Process	Major End Products	End Product Distribution		
		Gas	Liquid	Solid
Combustion	Heat, Ash	85 – 100	0	0 - 15
Gasification	Syngas, Char or Ash	85 – 95	0 - 5	5 - 15
Fast Pyrolysis	Syngas, Bio-oil, Bio-char	20 - 40	40 - 70	10 – 25
Slow Pyrolysis	Syngas, Bio-char	40 - 75	0 - 15	20 - 60

Table TCC.4: Percent of Feedstock Solids, Nitrogen, and Phosphorus Retained[1] in Char or Ash residual.

Thermochemical Conversion Process	Temperature Range (°F)	TS Retained in Ash/Char (%)	TN Retained in Ash/Char (%)	TP Retained in Ash/Char (%)
Combustion	1,500 – 3,000	Ash + 0.15 (100 - Ash)[2]	5	100
Gasification	1,500 – 2,700	Ash + 0.15 (100 - Ash)	15	100
Gasification	<1,500	Ash + 0.15 (100 - Ash)	75	100
Fast Pyrolysis	750 – 1,100	Ash + 0.25 (100 - Ash)	25	100
Slow Pyrolysis	575 – 1,475	Ash + 0.60 (100 - Ash)	75	100

[1]Percent Removed from Manure Handling = 100 – Percent Retained in Char or Ash Residual
[2]Ash Content of Feedstock (%TS)

Defined Transfer Efficiencies based on Process Factors

If operating temperature of a given process is known, the transfer efficiencies given in Table TCC.5 may be used as inputs to the Chesapeake Bay Model.

Table TCC5: Defined Transfer Efficiencies of Thermochemical Conversion Processes based on Process Factors.

Thermochemical Conversion Process	Operating Temperature (°F)	Transfer Efficiency (%)		
		NVE	NSE	PSE
Combustion	1,500 – 3,000	95	5	100
Gasification	1,500 – 2,700	85	15	100
Gasification	<1,500	25	75	100
Fast Pyrolysis	750 – 1,100	75	25	100
Slow Pyrolysis	575 – 1,475	25	75	100

Ancillary Benefits of Thermochemical Processes

Energy Production

Just like other plant-based biomass, there is energy in manure. As a general rule, animal manures can have energy values approaching 8,000 BTU/lb (dry basis). Table TCC5 lists typical energy values for various types of animal manure in comparison with other energy sources. This value can vary tremendously depending on the moisture and ash contents. As would be expected, the higher the moisture and ash content the lower the energy value. It should also be noted that sand and other bedding materials may influence not only the high heat value (HHV), but also the distribution and quality of thermochemical process end products.

Table TCC.6. Typical Energy Values of Manure, Biobased Products and Coal (From He et al., 2000: McKendry, 2002; Tumurulu, 2011; Cantrell et al., 2012).

Feedstock	Ash (%)	High Heat Value (BTU lb^{-1} TS db)
Dairy Manure	24.2	8,990
Beef Feedlot Manure	28.7	8,770
Swine Manure	32.5	9,080
Poultry Litter	30.7	8,180
Switchgrass	9.8	7,000
Wood Waste	42.0	5,030
Coal (Central Appalachian – Long Fork)	11.5	12,110